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Ecological study of Lumbricidae (Oligochaeta) in Norwegian coniferous forest soils*)

GUNNAR ABRAHAMSEN

With 7 figures

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Contents

1. Introduction

The decomposition of organic matter in the soil and the formation of soil profiles are influenced by activities of soil animals. To understand the role of the animals in this connection, information on the abundance of different species and groups of animals in various soils is necessary. Such information is also useful in connection with classification of soils, and in studies on the influence on the soil fauna of various methods used to stimulate the primary production (e. g. ABRAHAMSEN 1970).

In a previous study (ABRAHAMSEN 1972) the abundance of various enchytraeid species in the soils of different vegetation types in coniferous forests was given. To my knowledge similar data on earthworms from the Nordic countries are not available. BORNEBUSCH (1930) examined just a few localities in coniferous forest, and PEREL's (1964) results from U.S.S.R. cannot be transferred to the Nordic countries because of different soils and different species composition. Other studies in woodlands have mainly been performed in deciduous forests (e. g. DRIFT 1951, SATCHELL 1967). This paper, therefore, reports the results of earthworm studies on some of the vegetation types which were previously examined for enchytraeids.

2. Study areas and sample plots

The sample plots used in the present study are the same as those previously described (ABRAHAMSEN 1972), and only a brief description is required in the present paper. In three areas in South-Eastern Norway sample plots were placed in different vegetation types in coniferous forests. In relation to Oslo area A is situated 30 km south, area B 60 km north and area C is ca. 85 km south-west.

*) Contribution from the Forest Soil Fertilization Research Group, Ås-NLH, Norway

Table 1 Approximate dates of yearly normal air temperature and precipitation for the study areas

Study area	Temperature	Precipitation	General climate
A	5.5 °C	870 mm	Humid
B	3.3 °C	1080 mm	Superhumid
C	3.8 °C	1300 mm	Superhumid

The designation of the general climate is according to HESSELMAN (1932).

Characteristics of the vegetation and soil of the sample plots are given in Table 2. It should be noticed that two sample plots in area A (no. 9 and 10) had been placed on the same vegetation type, viz. the Melico-Piceetum typical subassociation. These sample plots were slightly different with regard to humus, soil profile and age of the trees. The designation of the textural classes is based on the soil texture triangle of the U.S. Department of Agriculture (e. g. KOHNKE 1968).

3. Methods

SATCHELL (1969, 1970) has reviewed the methods used for estimating earthworm populations. In the present study two of these methods have been used, viz. formalin extraction (RAW 1959) and extraction in modified Baermann funnels (O'CONNOR 1955).

The formalin extraction was carried out by applying 0.27 % formalin solution according to the procedure mentioned by SATCHELL (1969, 1970). The extraction was carried out on all sample plots mentioned in Tab. 2 and also on the Cladonio-Pinetum in area A and the Barbilophozio-Pinetum in area B and C (see ABRAHAMSEN 1972). On the sample plots (each on 100 sq.m.) in area A 6 squares of 0.5 sq.m were extracted. In area B and C smaller sample plots had been laid out (24.5 sq.m) and the formalin applications were carried out outside the sample plots. In the two last-mentioned areas no earthworms were found, probably because of the low soil moisture in the sampling period. For this reason, but mainly because the method is very area-consuming, repeated formalin extractions were not carried out.

Further studies were, therefore, carried out by using modified Baermann funnels. To utilize an available soil corer and the Baermann funnels previously used for extractions of enchytraeids, soil cores with diameter 9.1 cm and depth 10 cm were collected. To examine the vertical distribution each core was divided into two horizontal slices of 5 cm. Because of the experience from the enchytraeid study and the formalin extraction in area A, the sampling was confined to the vegetation types mentioned in Table 2, viz. the spruce forests and the richest pine forest vegetation type, the Vaccinio-Pinetum association. In area A simple random samples with 30 sample units (soil cores) were taken from each sample plot. In area B and C each sample plot was divided into 8 strata (squares) of 1.75 by 1.75 m. Three sample units were collected from each stratum, so that 24 units were taken from each sample plot. Within the study areas one sample (30 or 24 sample units) was taken from each sample plot simultaneously. This means that 150 sample units were collected simultaneously from area A, and 120 units were collected from each of the two other study areas. However, to obtain some knowledge on the seasonal variation in the abundance, samples (with 30 sample units) from one of the two plots at the *Me-Pc ty* subassociation in area A were collected at monthly intervals from June 1 to November 1 (sample plot no. 9). The sampling program is summarized in Table 3. The soil slices were put into individual plastic bags and stored at 2–3 °C until extraction took place. No soil cores were stored more than 14 days.

Some modifications of the Baermann funnels because of the large soil cores used in the present study meant that the temperature increase was slightly smaller than described by O'CONNOR (1962). The extraction efficiency was, however, examined by hand-sorting a large number of extracted soil cores. Altogether 576 earthworms were extracted and 53 individuals (9 %) were found by the subsequent hand-sorting. Of the latter individuals 28 had injured anterior part of the body. These injuries were caused by the sampling. Injured animals with intact anterior part seemed to be able to escape from the soil during the extraction. However, as only animals with intact prostomium were included in the counts the number of unextracted worms could be reduced to 25. This means that the efficiency of the Baermann extraction is probably ca. 95 %.

The nomenclature is as used by STØP-BOWITZ (1969). The identification of immature specimens was carried out by considering the identified mature specimens and by using a key for

Table 2 Description of the sample plots

Sample plot		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vegetation type[1])	Association	Vaccinion Pinetum			Eu-Piceetum					Melico Piceetum						
	Subassociation				Myrtillus			Dryopteris		Typical				Athyrium		
Study area		A	B	C	A	B	C	B	C	A_1	A_2	B	C	A	B	C
Altitude (m)		100	330	450	100	500	450	330	470	100	100	400	470	100	400	450
Cover of tree layer (%)		40	50	30	40	10	10	10	50	60	60	40	10	60	10	40
Age of forest		110	50	70	90	100	80	100	80	50	85	110	90	50	100	40
Soil profile		← Irone podsols →								Brown earth	← Semipodsol →			← Brown earth →		
Humus		← 5—7 cm, raw humus layer →								Mull	← Moder →			Mull		
Textural classes		Loamy sand	Sandy loam	Loamy sand	Sandy loam	Silt loam	← Sandy loam →							Loam	Loam	Sandy loam

1) Abbreviations: Vaccinion Pinetum: *Va-Pn*; Eu-Piceetum Myrtillus: *Eu-Pe My*; Eu-Piceetum Dryopteris: *Eu-Pe Dr*; Melico-Piceetum typical: *Me-Pe ty*; Melico Piceetum Athyrium: *Me-Pe At*

Description of the vegetation types is given by DAHL et al. (1967) and reviewed by ABRAHAMSEN (1972).

Table 3 Sampling program in the study areas (area in sq.m)

Study area	Extraction	Size of sample plot	Size of strata	Number of sample units per sample plot	Sampling date
A	Formalin	100	—	6[1]	Oct. 14–15, 1968
	Baermann	100	—	30[2]	June 1[3], July 1[4], Aug. 1[4], Sept. 1[4], Okt. 1[4], Nov. 1[4] 1969
B	Baermann	24.5	3.06	24[2]	Oct. 14, 1969
C	Baermann	24.5	3.06	24[2]	Sept. 2, 1969

1) Sample unit area 0.5 sq.m; 2) Sample unit area 65.0 sq.cm; 3) All sample plots; 4) The sample plot (no. 9) with the *Me-Pc ty* (A_1) only.

immature specimens given by STØP-BOWITZ (1969). It should be stressed, however, that the only juvenile specimens that could be conclusively identified belonged to *Dendrobaena octaedra* and *Allolobophora rosea*. See Table 5 for authorities for scientific names.

4. Results

4.1. Soil moisture and temperature

Soil temperature and soil moisture in per cent of the water-holding capacity at pF 0.5, at the dates for sampling are given in Table 4. On the *Me-Pc ty* A_1 (area A) where monthly samples were collected, the variation in soil temperature and moisture from June to November was as shown in Figure 1. The figure also gives the daily variation in precipitation and mean air temperature recorded at Ås weather station, run by the Department of Physics and Meteorology at the Agricultural College of Norway.

4.2. Lumbricid fauna

4.2.1. *Sampling technique*

In connection with sampling of soil cores the number of individuals per soil core is important for the precision of the estimated densities. Figure 2 gives the relation between the mean number of individuals per soil core and the coefficient of variation ($\frac{s}{\bar{x}} \cdot 100$). The calculations were carried out for all populations denser than ca. 0.1 individual per soil core (ca. 15 per sq. m).

The coefficient of variation is in general only slightly larger than might be expected if the earthworms had been randomly distributed (Poisson distribution). The accordance

Table 4 Soil temperature (°C) and soil moisture in per cent of the water-holding capacity at pF 0.5 on the various sample plots at the sampling date (in 2.5 cm soil depth)

Vegetation type:	*Va-Pn*	*Eu-Pc My*				*Eu-Pc Dr*		*Me-Pc ty*						*Me-Pc At*			
Study area:	A[2]	A[1]	A[2]	B[1]	C[1]	B[1]	C[1]	A_1[1]	A_1[2]	A_2[1]	A_2[2]	B[1]	C[1]	A[1]	A[2]	B[1]	C[1]
Soil temperature	9	9	8	5	11	5	10	*)	6	9	7	6	11	9	7	6	12
Soil moisture	43	54	44	49	77	43	27	*)	41	55	39	41	43	61	52	44	50

1) Baermann funnel; 2) Formalin extraction; *) See Fig. 1.

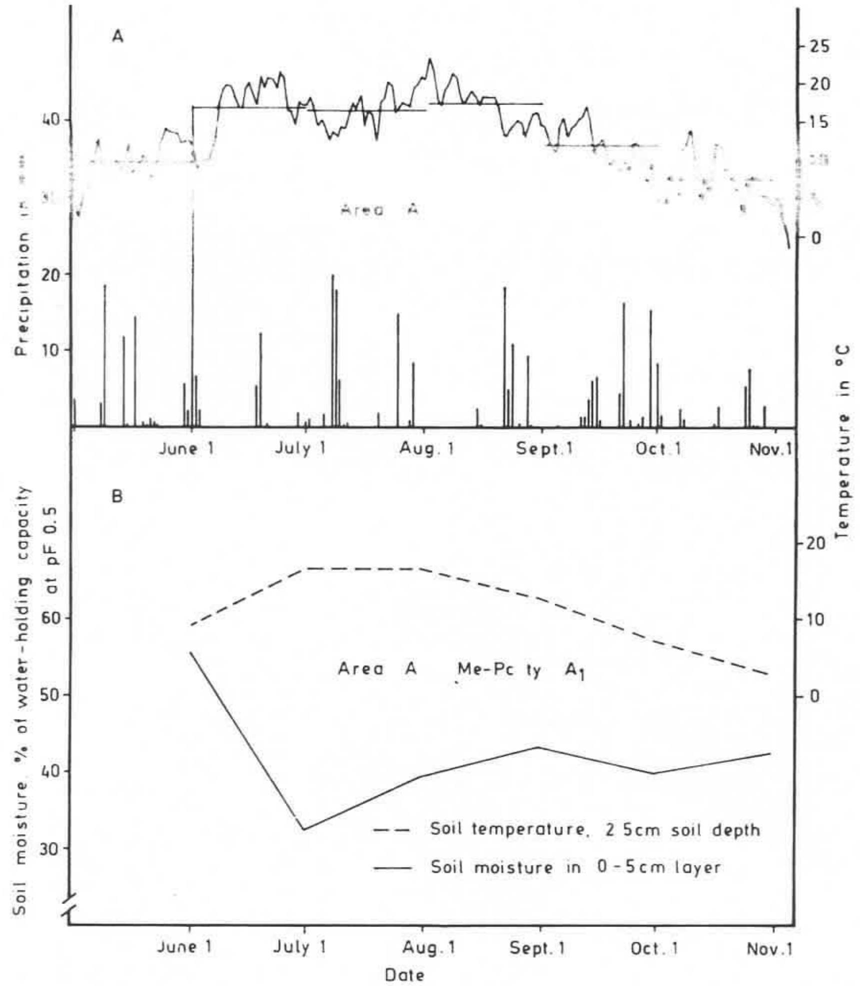

Figure 1. A. Daily variation in mean air temperature and precipitation observed at the weather station at Ås (area A). B. Seasonal variation in soil temperature and soil moisture (per cent of the water-holding capacity at pF 0.5) at the dates for sampling.

with the Poisson distribution was supported, as only ca. 20% of the population counts were not fitted by the Poisson distribution.

Nine density estimates were based on stratified random samples collected from strata of ca. 3 sq. m. Compared with simple random sampling this stratification increased the precision in 7 estimates and decreased it in 2. The highest gain in precision measured by difference in standard deviation of the mean, was ca. 15%. The greatest decrease in precision was also ca. 15%.

The purpose of the sampling procedure was also to discover most of the species in the population. In this connection the "minimal area" or minimal number of individuals necessary to discover a certain proportion of the species in the population is of interest. Figure 3 indicates that more species will probably not be discovered if the number of individuals is greater than ca. 20.

4.2.2. *Abundance and species composition*

The soil cores were intended to be 10 cm deep, but the semipodsol and podsol soils in area B and C contained so much stone that some soil cores from these areas were only slightly deeper than 5 cm. However, no earthworms were observed below 5 cm in these soils. Therefore, all abundances given here are based on the number observed in the upper 10 cm of the soil.

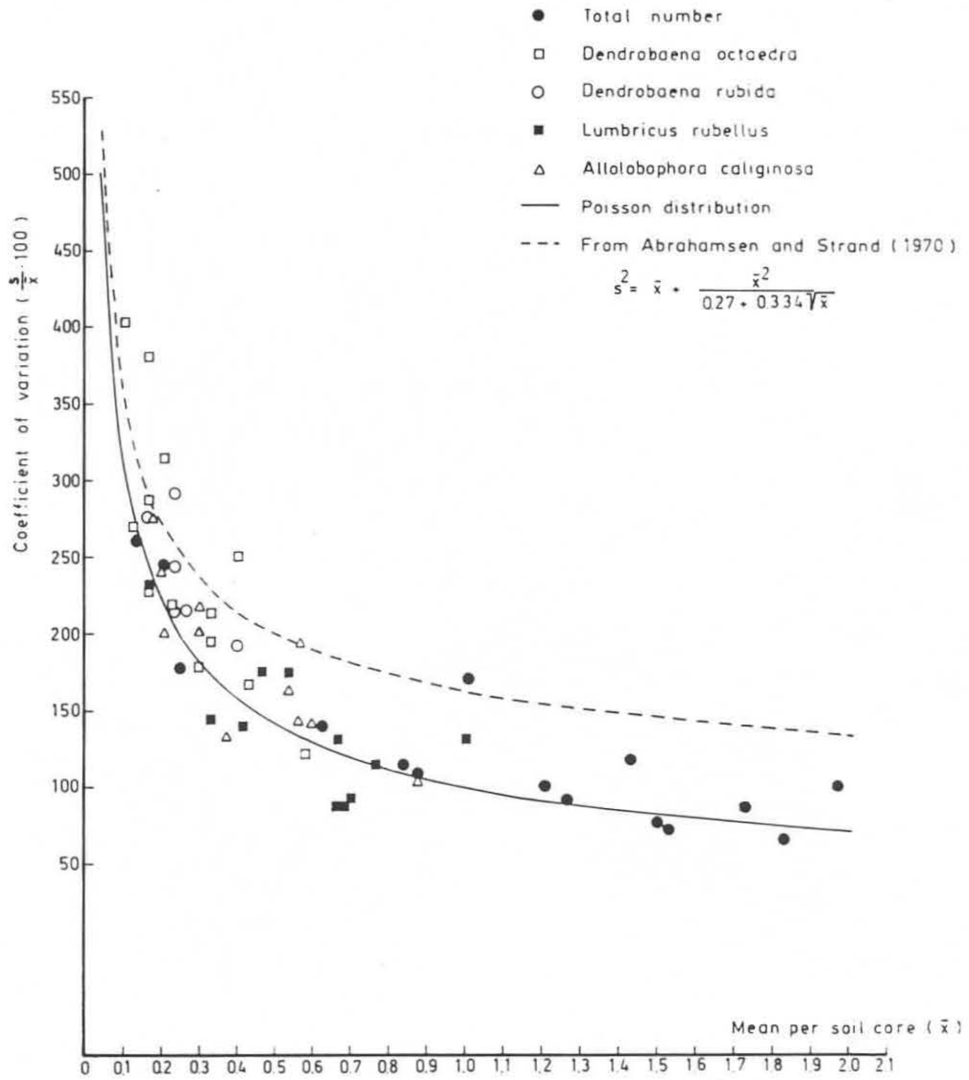

Figure 2. Relation between the coefficient of variation and the mean abundance per soil core.

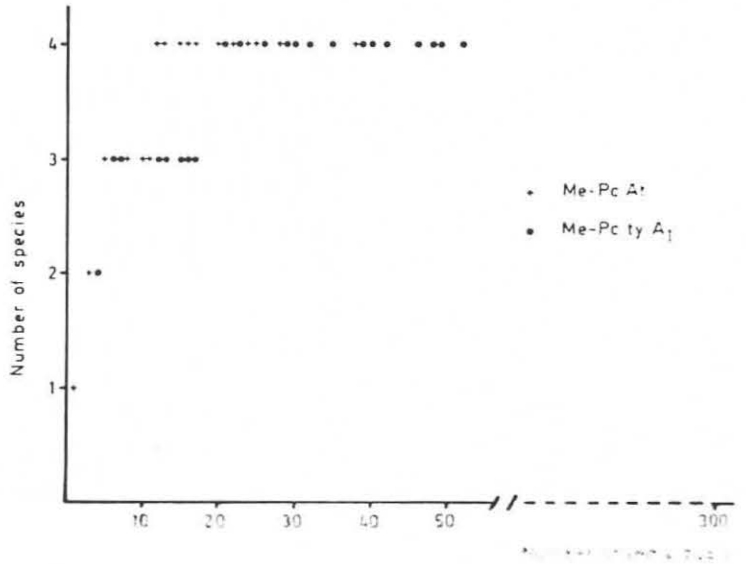

Figure 3. "Minimal area curve". Relation between number of species and number of individuals observed.

Observations of the variation in the abundance from June to November on the *Me-Pc ty* (A_1) revealed no significant variation either in the total abundance or in the abundance of the various species (Figure 4).

Table 5 gives the abundance of the different species registered at the various sample plots. In Figure 5 the abundances are given in percentage of the highest average density per sample plot observed for the species in question. The figures above the histograms give the average abundance per soil core, the standard deviation, and the total number of sample units collected from the different vegetation types. The confidence intervals of the contrasts significant at the 95 % level are also presented. The data from the formalin extraction are not included in these calculations.

The total abundance of earthworms increased significantly from the pine forest by the Eu-Piceetum to the Melico-Piceetum association. Significant differences were not found between the two Eu-Piceetum subassociations nor between the two Melico-Piceetum subassociations. The populations in the Athyrium subassociation seemed however, in general to be larger than in the typical subassociation.

D. octaedra and *L. rubellus* were the two dominating species on all sample plots. *D. octaedra* was significantly more abundant in the *Me-Pc ty* than in both the Athyrium subassociation and the Eu-Piceetum association. The data from the formalin extraction revealed small differences among the vegetation types.

L. rubellus was most abundant in the *Me-Pc* association and significant differences between the two subassociations could not be found. The species was very rare on poorer sites than the *Me-Pc ty*.

A. caliginosa was the only abundant species restricted to the *Me-Pc* association. This species was also significantly more abundant in the Athyrium subassociation than in the typical subassociation.

The other species recorded in the present study were rare. *D. rubida* seemed to be most common in the *Me-Pc ty* subassociation. *A. rosea* and *L. terrestris* were found only in the *Me-Pc* association. The latter species was found only by means of the formalin method.

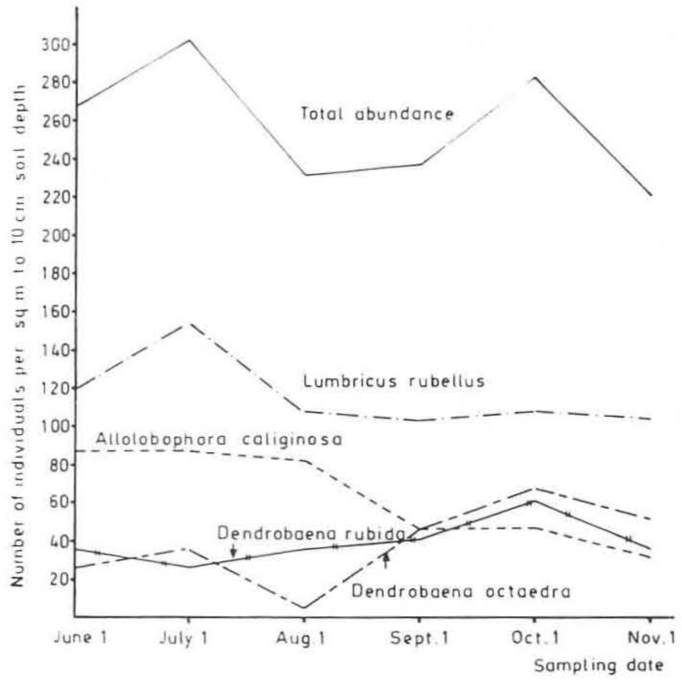

Figure 4. Variation in the abundance of earthworms from June to November at the *Me-Pc ty* A_1 sample plot.

4.2.3. *Vertical distribution*

Variation in the vertical distribution of earthworms from June to November in the *Me-Pc ty* A_1 is shown in Figure 6A.

The vertical distribution of the total earthworm population varied among the vegetation types (Figure 6B). The most even distribution was found in the brown earth of the *Me-Pc At.*

D. octaedra was the most epedaphic species recorded (Figure 6C) and no individuals were extracted from the 5 to 10 cm soil layer. *A. caliginosa* was the most euedaphic species in the present study.

5. Discussion

In the present study no comparison of the efficiency of the Baermann funnels and formalin extraction was carried out. Nevertheless it seems that the Baermann funnels are most efficient, as all densities but one obtained by this method were higher than those obtained by the formalin method. The latter method has also only been recommended

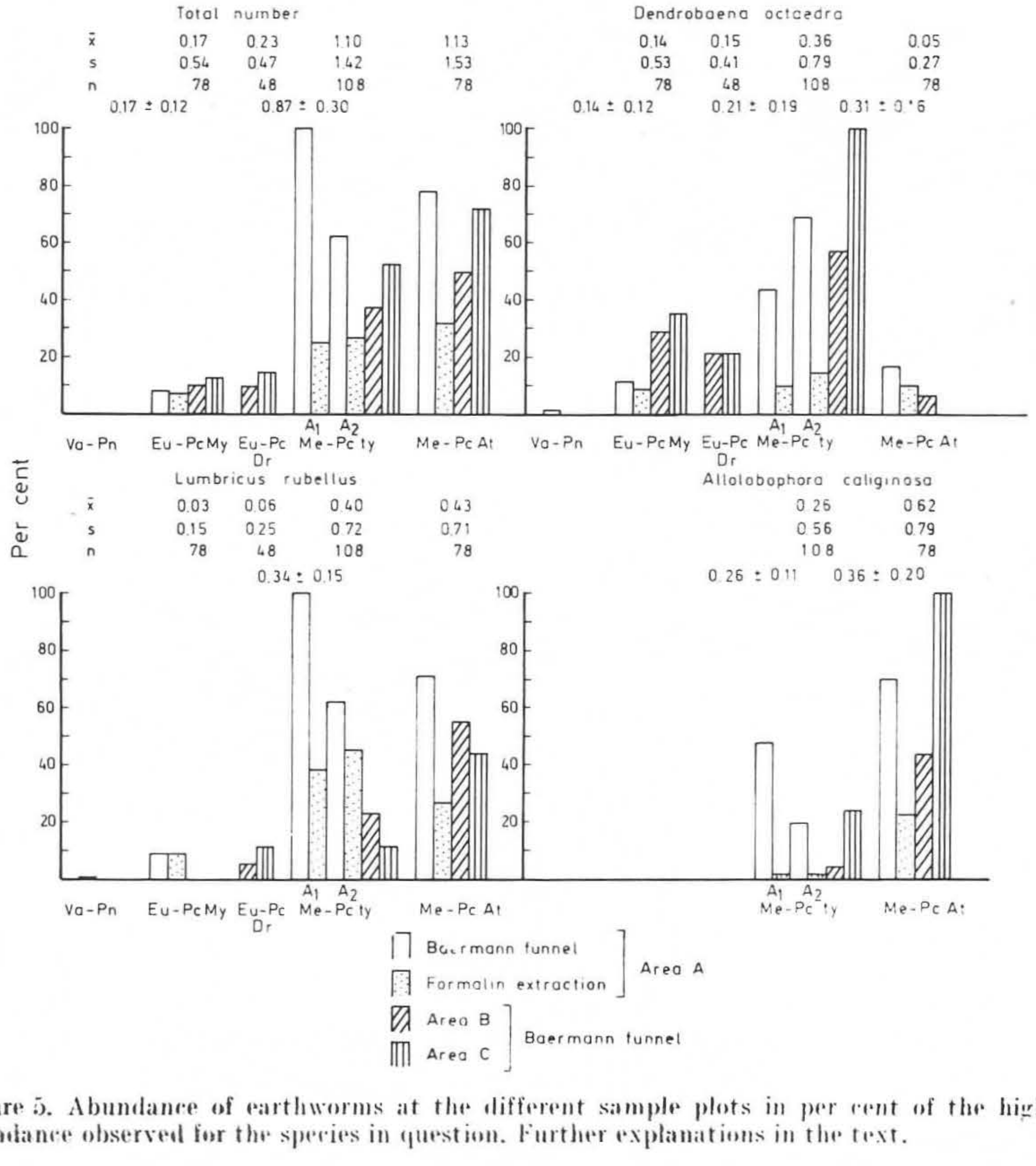

Figure 5. Abundance of earthworms at the different sample plots in per cent of the highest abundance observed for the species in question. Further explanations in the text.

Table 5 Species composition and abundance per sq.m of earthworms at the different sample plots

Vegetation type	*Va-Pn*				*Eu-Pc My*				*Eu-Pc Dr*		*Me-Pc ty*						*Me-Pc At*			
Study area	A	A	B	C	A	A	B	C	B	C	A_1	A_1	A_2	A_2	B	C	A	A	B	C
Extraction method*)	BF	Form	BF	BF	BF	Form	BF	BF	BF	BF	BF	Form	BF	Form	BF	BF	BF	Form	BF	BF
Dendrobaena octaedra (SAVIGNY, 1826)		0.7	—	—	10	8	26	32	19	19	26	9	62	13	51	90	15	9	6	—
Lumbricus rubellus (HOFFMEISTER, 1843)		0.7	—	—	10	5	—	—	—	—	10	11	21	17	—	—	5	2	6	—
L. rubellus juv.						5	—	—	6	13	108	33	51	35	26	13	77	29	58	51
Dendrobaena rubida (SAVIGNY, 1826)										—	—	4	—	1	—	—	—	—		
D. rubida juv.										6	36	3	—	—	13	—	—	0.3		
Allolobophora caliginosa (SAVIGNY, 1826)											15	—	6	1	—	19	26	1	—	26
A. caliginosa juv.											72	2	20	1	6	13	67	29	58	107
Allolobophora rosea (SAVIGNY, 1826)												0.3	—	—	—	—	10	1		
A. rosea juv.												—	—	—	—	—	—	7		
Lumbricus terrestris (LINNÉ, 1758)												0.3	—	—	—	—	—	1		
L. terrestris juv.																		2		
Number of species		*2*	—	—	*2*	*2*	*1*	*1*	*2*	*3*	*4*	*6*	*3*	*4*	*4*	*3*	*4*	*6*	*3*	*2*
Total number of individuals per sq.m	—	**1.4**	—	—	**20**	**18**	**26**	**32**	**25**	**38**	**267**	**63**	**160**	**68**	**96**	**135**	**200**	**81**	**128**	**184**

*) Number of recorded specimens is obtained by using the following multiplication factors:
Form = Formalin extraction: ×3
BF = Baermann funnel area A: *Me-Pc ty* A_1: ×1.170, the others: ×0.1950
Baermann funnel area B and C: ×0.1560

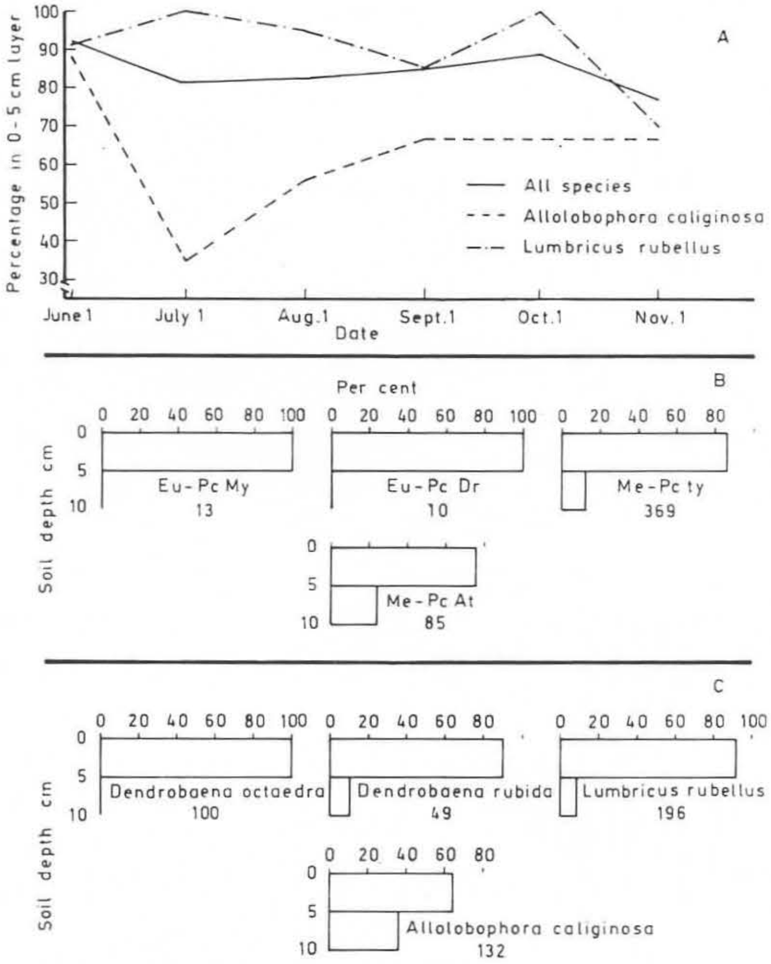

Figure 6. Vertical distribution of earthworms. A. Seasonal variation at the *Me-Pc ty* A_1 sample plot. B. Variation among the vegetation types (all species). C. Variation among species. The figures below the histograms give the number of individuals of the species.

for studies of *L. terrestris* and not for horizontal burrowing species (*D. octaedra*, *D. rubida*, *L. rubellus*) or for aestivating species (*A. caliginosa*) (e. g. SATCHELL 1970). It is, therefore, of some interest to note that *L. terrestris* was only observed by means of the formalin method. However, it should also be stressed that the total soil area extracted per sample plot in the Baermann funnels was 0.195 sq.m in area A and 0.156 sq.m in area B and C. By the formalin method 3 sq.m were examined at each sample plot. This implies that more rare species were likely to be found by means of the formalin extraction than by the extraction in Baermann funnels. By the latter method populations below 5 to 7 individuals per sq.m were unlikely to be found. The abundances in pine forests and the abundances of *A. rosea* and *L. terrestris* seemed to be below this limit.

More precise estimates of the population densities could have been obtained if larger sample units had been used. The small overdispersion observed in the present study should, however, be noticed. In other earthworm studies where larger sample units have been used, the individuals were most often found to be aggregated (e. g. SATCHELL 1967). It is therefore, possible that the increase in precision by increasing the sample unit area within some limits, may to some extent be compensated by a greater variation due to greater overdispersion. This problem is, however, not quite clear, as previous studies have shown that the parameter k of the negative binomial distribution increases with increasing population density (BERTHET and GÉRARD 1965, ABRAHAMSEN and STRAND

Table 6 The similarity in the oligochaet fauna among the sample plots given by the quotient of similarity (in %)

Vegetation type:	Study area	*Cl-Pn*[1])	*Ba-Pn*[2])		*Va-Pn*			*Eu-Pe My*			*Eu-Pe Dr*		*Me-Pe ty*				*Me-Pe At*		
		A	C	B	C	B	A	C	B	A	C	B	C	B	A_2	A_1	C	B	A
Me-Pe At	A	32.3	21.4	14.8	27.6	14.1	37.5	32.3	33.3	48.5	41.2	38.7	64.9	50.0	57.9	65.0	83.7	79.1	
	B	16.7	19.0	20.0	27.3	20.0	32.0	33.3	26.1	46.2	37.0	41.7	60.0	58.1	58.1	60.6	88.9		
	C	33.3	19.0	20.0	27.3	20.0	40.0	25.0	26.1	46.2	37.0	41.7	60.0	58.1	58.1	60.6			
Me-Pe ty	A_1	57.1	22.2	11.8	31.6	23.5	54.5	47.6	40.0	60.9	66.7	47.6	74.1	69.2	71.4				
	A_2	52.6	37.5	26.7	47.1	26.7	70.0	63.2	55.6	76.2	81.8	63.2	88.0	83.3					
	B	35.3	28.6	30.8	26.7	15.4	55.6	47.1	50.0	63.2	70.0	70.6	69.6						
	C	44.4	40.0	28.6	50.0	28.6	63.2	55.6	58.8	80.0	66.7	66.7							
Eu-Pe Dr	B	33.3	44.4	50.0	40.0	25.0	61.5	50.0	72.7	85.7	66.7								
	C	66.7	50.0	36.4	61.5	36.4	75.0	80.0	71.4	82.4									
Eu-Pe My	A	57.1	54.5	40.0	66.7	40.0	80.0	71.4	76.9										
	B	54.5	75.0	57.1	66.7	28.6	66.7	72.7											
	C	66.7	66.7	50.0	80.0	50.0	76.9												
Va-Pn	A	76.9	60.0	44.4	72.7	44.4													
	B	50.0	40.0	50.0	66.7														
	C	80.0	85.7	66.7															
Ba-Pn[2])	B	25.0	80.0																
	C	44.4																	

1) Cladonio-Pinetum.
2) Barbilophozio-Pinetum.

1970). On the other hand G. GÉRARD (1967) observed for soil mites that k seemed to be almost independent of the sample unit area when varying from 36 to 144 sq.cm. If GÉRARD's observation has general validity, the increase in precision by increasing the sample size (and thereby the total sampled area) is not so great as often supposed (e. g. ABRAHAMSEN 1969).

The minimal number of individuals necessary to observe most earthworm species in the populations seemed to be ca. 20. This number is smaller than the number of individuals observed in the poorest vegetation types. In these types however, the "minimal number" is presumably smaller than in the richest soil types. It should, however, be stressed that the method of removing soil cores from the field may mean that burrowing species like *L. terrestris* are underestimated.

Previous studies on earthworms in the Nordic countries have revealed that *D. octaedra* was the only, or at least the only abundant, earthworm species in coniferous forest soils (BORNEBUSCH 1930, FORSSLUND 1944). More recent studies have, however, revealed that also *D. rubida*, *Dendrobaena subrubicunda* (EISEN 1874), *L. rubellus*, *Lumbricus castaneus* (SAVIGNY 1826) and *A. rosea* can be found in Nordic coniferous forests (KARPPINEN and NURMINEN 1964, HUHTA et al. 1967, LJUNGSTRÖM 1967). From podsolic coniferous forest soils in U.S.S.R. PEREL' (1964) has reported *D. octaedra* as the dominating species and sporadic occurrences of *Bimastus tenuis* (EISEN) which according to STØP-BOWITZ (1969) is identical with *Dendrobaena tenuis* (EISEN 1874). In semipodsols *Octolasion lacteum* (ORBY 1881) was observed and in even better soil *L. rubellus* was also found. German studies have demonstrated that *D. octaedra*, *D. rubida* and *L. rubellus* are typical species of coniferous forest (RONDE 1960, SCHWENKE et al. 1970). Under increasingly eutrophic conditions in England *D. rubida* and *L. rubellus* decrease in abundance and on coniferous moor *D. octaedra* and *Bimastus eiseni* (LEVINSEN 1884) are the only remaining species (SATCHELL 1967).

It is seen that there is considerable geographical variation in the species composition of earthworms in coniferous forests. In the Nordic countries, however, *D. octaedra* and

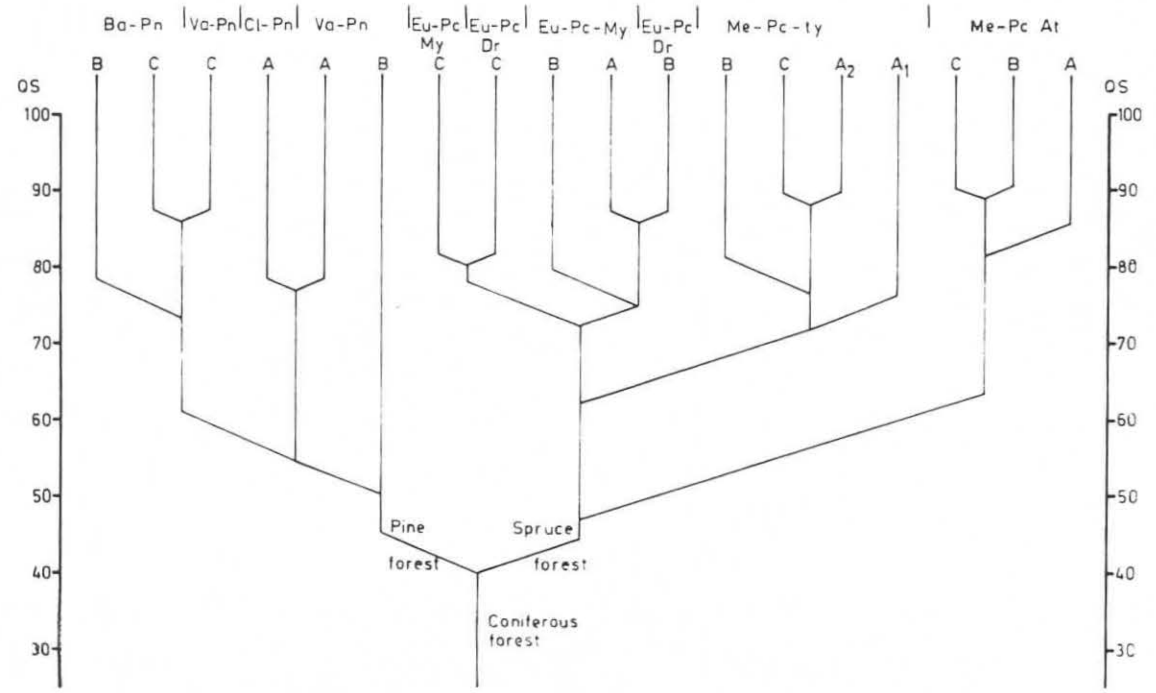

Figure 7. Classification of the sample plots by applying the quotient of similarity on the oligochaet fauna. Further explanations in the text.

L. rubellus seem to be most typical. The former species dominates in podsolic soils, the latter in semipodsols and brown earth. According to the present study, *A. caliginosa* may be as abundant as *L. rubellus* in the last mentioned soils.

In the previous study (ABRAHAMSEN 1972) the 18 sample plots were grouped according to a classification technique proposed by SORENSEN (1948). The grouping was carried out both for the vegetation and for the enchytraeid fauna, but the results obtained were not identical. The discrepancies were most conspicuous among the poorest soil types. The classification of the fauna was, however, based on a small number of species and the classes obtained would presumably be more representative for the total soil fauna if earthworms were also included. Table 6 gives the quotient of similarity between the sample plots when both enchytraeids and earthworms were considered and Figure 7 shows the result of the classification. The grouping shown in the figure agrees better with the vegetation types than the grouping based on enchytraeids only. Of particular interest is the conspicuous difference in the oligochaet fauna between spruce and pine forest. The most important difference between spruce and pine forest soil from a chemical point of view is the higher content of total nitrogen in spruce forest than in pine forest (DAHL et al. 1967).

Differences were also observed in the abundance of earthworms between pine and spruce forests. In pine forests no earthworms were found by means of the sampling connected with the Baermann technique. The abundances observed in spruce forests were on the other hand relatively high. BORNEBUSCH (1930) observed 18 to 31 individuals per sq.m in raw humus and ca. 100 in brown earth. In U.S.S.R. less than 10 individuals per sq.m have been found in podsol soils and from 13 to 110 individuals per sq.m in more nutritious soils (PEREL 1964). The abundance observed in brown earth and semipodsols in the present study are similar to those reported from deciduous forests and orchards (e. g. PEREL' 1964, SATCHELL 1967). The high abundances in the present study are probably explained by the extraction method yielding a high number of small, juvenile individuals. Handsorting, which was the method used in most of the mentioned studies, may produce a significant underestimation of the abundances of small individuals (RAW 1960, NELSON and SATCHELL 1962, AXELSSON et al. 1971).

The decrease in soil moisture from June 1 to July 1 has not noticeably influenced the abundance of most earthworm species (Figures 1 and 4). The soil moisture may, however, have influenced the vertical distribution of *A. caliginosa* as the smallest percentage of individuals in the 0—5 cm soil layer was found in July when the soil moisture was below 35 % of the water-holding capacity. This indicates that the species is related to soil moisture as are probably most enchytraeid species. For the most abundant enchytraeid species in coniferous forest soil it has been demonstrated that the optimal moisture for the population growth was between 50 and 95 % of the water-holding capacity, but the growth rate was not seriously reduced before the moisture dropped below 20—30 % (ABRAHAMSEN 1971). In a field study underoptimal moistures could not be detected by reduced abundance, but by changes in the vertical distribution (ABRAHAMSEN 1972). It may therefore be suggested that 35 % soil moisture is under-optimal for *A. caliginosa*. Significant variations in vertical distribution of *A. caliginosa* have previously been demonstrated by M. B. GERARD (1967). He observed also that temperatures below ca. 5 °C make earthworms move deeper into the soil. Similar behaviour was indicated for *D. rubida* and *L. rubellus* in the present study.

No species displayed any conspicuous variation in vertical distribution among the vegetation types. The variation in vertical distribution of the whole earthworm population is, therefore, explained by the variation in species composition among the vegetation types. The even distribution in brown earth is caused by the high abundance of *A. caliginosa*.

The superficial distribution in podsols on the other hand, is caused by the dominance of the epedaphic species *D. octaedra* and *L. rubellus*.

By considering the acidity of the soils at the different sample plots (ABRAHAMSEN 1972) the following relations between the distribution of earthworms and pH of the soil can be found:

D. octaedra (3.9—6.4); *L. rubellus* (4.0—6.4); *D. rubida* (4.2—6.4); *A. caliginosa* (4.3—6.4); *A. rosea* (4.6—6.4); *L. terrestris* (4.6—6.4).

D. octaedra was observed in the present study in more basic soil than previously observed (SATCHELL 1955, 1967). It should, however, be stressed that the variation in pH in the most basic soil was between 5.9 and 6.9. This means that *D. octaedra* may have been located in microhabitates with lower pH than the average value for the sample plot.

6. Summary

The abundance and species composition of earthworms have been studied in the soil of different vegetation types in coniferous forests. The study is a continuation of a similar study on Enchytraeidae previously published.

The abundance varied from less than 10 to ca. 40 individuals per sq.m in iron podsol and from ca. 60 to 260 in semipodsols and brown earth.

The dominating species were *Dendrobaena octaedra* and *Lumbricus rubellus*. The former species was most abundant in semipodsol, the latter in semipodsol and brown earth. Both species were found in iron podsol. *Allolobophora caliginosa* was restricted to semipodsol and brown earth and was most abundant in the latter soil type.

Comments have also been made on the sampling methods, the vertical distribution and the classification of the soil fauna in relation to the vegetation types.

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Address of the author: GUNNAR ABRAHAMSEN, The Norwegian Forest Research Institute, N-1432 Ås-NLH, Norway.